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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 965

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ October 18, 1921

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CONTROL OF THE ARGENTINE ANT IN CALIFORNIA CITRUS ORCHARDS

By

R. S. WOGLUM, Entomologist, and A. D. BORDEN, Scientific Assistant, Fruit Insect Investigations

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By R. S. Woglum, *Entomologist*, and A. D. Borden, *Scientific Assistant, Fruit Insect Investigations.*[1]

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INTRODUCTION.

Supposedly introduced into the United States at the close of the nineteenth century the Argentine ant (*Iridomyrmex humilis* Mayr) has since become widely distributed through the more temperate regions, where its complete occupancy, in long-infested localities, and its omnivorous habit bear an important relation to crop production and food storage and rank it as one of the most annoying of household pests. Its discovery in 1908 in cities bordering San Francisco Bay resulted in the initiation of a control campaign under the direction of Prof. C. W. Woodworth, of the University of California, and subsequently led to the development of an arsenical poisoned sirup of considerable merit.

The Argentine ant was recorded in citrus orchards in California almost from the date of its reported presence in the State. It appeared to cause no alarm to orchardists, however, usually remained unnoticed except about the buildings, and where observed was classed merely as "an ant" whose presence was believed in no way detrimental to the trees. The rôle of the Argentine ant as an orchard pest in California was discovered by Mr. J. D. Neuls and the senior writer in 1915 while conducting an investigation of the common mealybug, and its very direct bearing on the control of the mealybug was conclusively proved by an extended series of experiments. This immediately led to an investigation into methods of ant control with which the junior writer became associated in 1917. The great success which attended these experimental efforts led to control demonstrations of considerable proportions in severely ant-infested communities and proved a stimulus to widespread interest in the pest. The demand for relief which followed this awakened interest has already resulted in the treatment of several thousand acres, from a very large part of which the ants have been totally eradicated. This bulletin presents the results of the various remedial methods pursued during the period 1915–1920 and gives full instructions for the control and eradication of ants in the citrus orchards of California.

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[1] Photographs by senior writer; figure 3 drawn by Miss A. Motter. Mr. Woglum resigned from the Bureau of Entomology September 11, 1920.

RELATION OF THE ANT TO THE CITRUS INDUSTRY.

The spread of the Argentine ant in California bears an important relation to citrus growing, a relation certain to become more prominent with wider distribution and long-established infestations. The very severe damage which this pest can sometimes do in citrus orchards has been impressively stated by Newell and Barber[2] as follows: The bearing qualities of an orchard are severely impaired by the second season of infestation, the crop is almost entirely lost by the third season, and the trees are dying by the fourth year of infestation. This conclusion is based on conditions in Louisiana, and in this respect it should be noted that no systematic effort is made in that State to control citrus scale pests. Such extreme damage has never been observed under California orchard conditions where fumigation and other insecticidal control measures are practiced constantly.

The damage to trees in ant-infested orchards in California does not arise from direct attacks on the blossoms, fruits, and roots, as has been reported from some regions, but is attributable very largely to its so-called symbiotic manner of living with mealybugs, aphids, and various scales, which results in their increase beyond all customary proportions. The constant attendance of the ant protects the mealybugs or scales from their natural enemies and results in their abnormal increase. (See fig. 1.) The degree of infestation is further stimulated and extended through the fact that the ant distributes these injurious insects to other parts of the tree or even to adjacent trees. The chief damage done by the Argentine ant in California citrus orchards has been through its relation to mealybug infestations, particularly the common mealybug, *Pseudococcus citri* (Risso). Prior to the reported presence of this ant in the Southwest, one species of mealybug was recorded as a serious citrus pest in only three or four limited districts, where it was characterized by sporadic outbreaks which would quickly disappear. In the last decade, which is contemporaneous with the Argentine ant invasion, the severe infestation of the common mealybug has increased many hundred per cent and districts have been invaded from which mealybugs were never before recorded.

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[2] NEWELL, WILMON, and BARBER, T. C. THE ARGENTINE ANT. U. S. Dept. Agr., Bur. Ent. Bul. 122, p. 192. 1913.

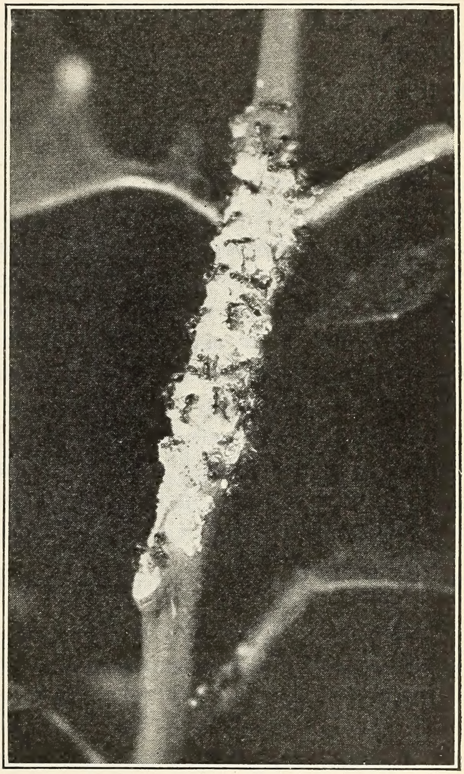

FIG. 1.—Ants attending a group of mealybugs. Their almost constant presence protects the mealybug from its natural enemies.

In the course of investigations under the direction of the senior writer to establish effective control of the common mealybug, *Pseudococcus citri* (Risso), it was discovered that the Argentine ant not only brings about increased severity of infestation but causes the mealybug to persist year after year. It was furthermore discovered that the common mealybug was attacked by many predatory insects, some of such high efficiency that in ant-freed territory they were capable of keeping the mealybug under commercial control except at those infrequent periods normal in the "ups and downs" of biologically controlled pests. Demonstrations carried out in several mealybug-ant infested orchards in the San Gabriel Valley during the years 1915 and 1916, in which alternate rows were kept free of ants, proved that trees rid of ants quickly become freed of mealybugs, although on adjacent ant-attended trees the mealybug infestation persists. The results of these demonstrations are verified by the fact that in every experiment performed by the writers during the period of 1915–1920 equally good results have been obtained. The eradication of the ant in every instance resulted in a reduction of the mealybug infestation to commercial control within a period of from 1 to 3 months. This has been largely due to the increased and unrestricted activity of predatory insects already established.

The citrophilus mealybug, *Pseudococcus gahani* (Green), was first recorded as an orchard pest in 1914 and has never been observed as a severe pest in citrus orchards except in localities infested with the Argentine ant.

The influence of the ant on increased severity of scale pests, while less important than on mealybugs, must be considered. The black scale, *Saissetia oleae* (Bern.), and soft brown scale, *Coccus hesperidum* L., have been observed to become decidedly more numerous on trees attended by large numbers of ants than in other parts of the same orchard entirely free of the ants. Trees severely infested with the soft brown scale have been rapidly freed by the action of parisitic insects following the control of this ant.

It is entirely possible that the Argentine ant distributes fungous and bacterial diseases, although no specific evidence has been noted. Attracted as they are by the honeydew of insects, their habit of carrying this and various other substances, both animal and vegetable, their colonization and movement over the ground, and their constant attendance to all parts of the trees offer ready means of distributing brown rot, gum disease, and other maladies of citrus. In this connection ants would appear to be especially deserving of attention in pear orchards through their possible relation to blight.

OTHER RELATIONS.

Beekeeping in sections heavily infested with the Argentine ant is most difficult and proves successful only after a strenuous campaign is instituted to control or exterminate the pest. The ant is exceedingly fond of honey and, furthermore, attacks the bee larvæ. The ant's small size, great numbers, and persistent effort to reach desired food make it an enemy with which the bees are unable to cope long.

As a household pest the Argentine ant has proved particularly annoying. It invades all parts of the house in search of food, and the intolerable conditions brought about in heavily infested districts render the houses less desirable for places of residence.[3]

DISTRIBUTION.

The Argentine ant appears to have been first noted in California in 1905 by Dr. E. S. G. Titus, at Ontario, although it did not come into prominence until 1908, when a general survey of its distribution was made by Prof. C. W. Woodworth, of the University of California. It was then reported as widely distributed about the San Francisco Bay region and in Southern California at Azusa and Upland. By 1910 the total territory involved was estimated at 4,000 acres in northern California and 1,000 acres in the southern part of the State. During the 10 years intervening between the second survey of Prof. Woodworth and to-day this ant has greatly extended its area of occupation, spreading into the great interior valleys of northern California, and including within its limits localities in every county in the south excepting one, as follows: Los Angeles, 39; San Bernardino, 8; Riverside, 4; Ventura, 5; Santa Barbara, 5; Orange, 10; San Diego, 6. Two heavy infestations have been observed on Catalina Island, off the mainland of Los Angeles County. (See fig. 2.) The infested territory appears to fall for the most part within cities and towns, although the country acreage concerned is very large, between 8,000 and 10,000 infested acres being known in citrus alone.

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[3] The rôle of this insect as a household pest has been fully described by Mr. E. R. Barber of this department in Farmers' Bulletin 1101, United States Department of Agriculture.

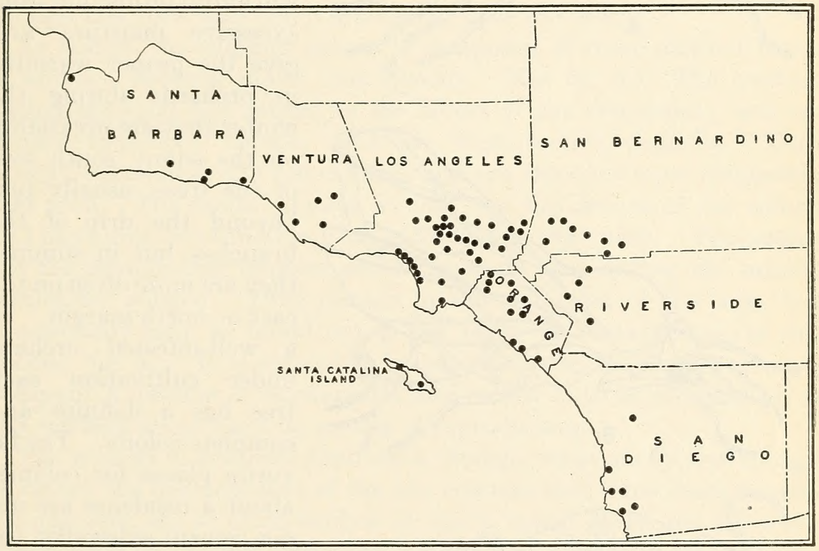

FIG. 2.—Present known distribution of the Argentine ant in Southern California.

Elsewhere in the United States the Argentine ant has been reported to occur in settled localities throughout the Southern States, being established as far north as Nashville, Tenn., and Raleigh, N. C. First described from Argentina it has since gained a foothold in other parts of South America, in the Madeira Islands, South Africa, and Germany.

CHARACTERISTICS AND HABITS.

The Argentine ant, like most other species of ants, forms definite colonies or ant communities under the surface of the ground. The colony or nest is an elaborate system of galleries and cells, closely connected, with usually only two or three openings to the surface. Though the galleries may cover an area of over 10 square feet they seldom are more than 8 or 10 inches in depth. Colonies are located in places which will afford protection from excessive moisture and give the proper warmth; in orchards during the winter they are invariably on the sunny south side of the trees, usually just beyond the drip of the branches, but in summer they are more often on the east or north margin. In a well-infested orchard under cultivation each tree has a definite and complete colony. The favorite places for colonies about a residence are under cement sidewalks, the foundations of the buildings, a pile of rubbish, the compost heap, or a chicken yard.

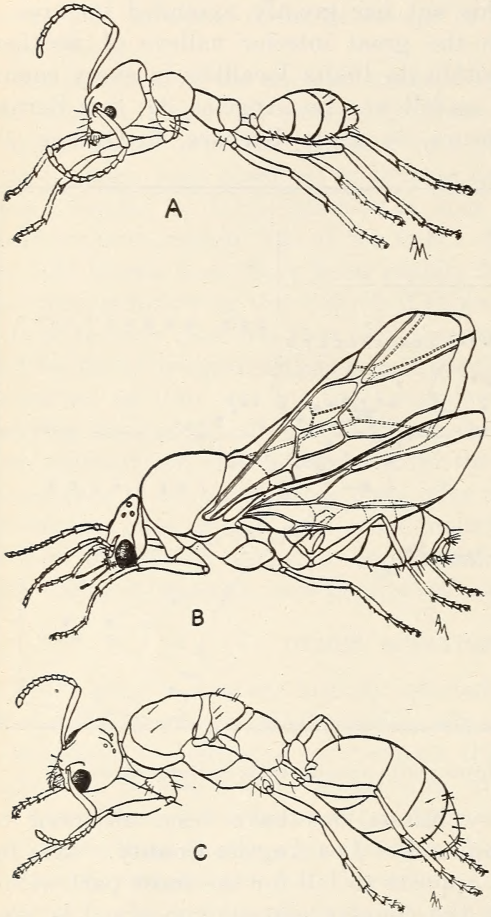

FIG. 3.—The Argentine ant: *a*, worker; *b*, male; *c*, queen. (Greatly enlarged.)

The size of the community varies greatly with the season, the food supply, and the age of the colony. In a normal summer colony the ants will be found in all stages of development—eggs, larvæ, pupæ, workers, males, and females—and the colony responds quickly to warm days and an abundance of food by increasing its numbers. If the colony grows rapidly and the food supply warrants it, or if the food supply is some distance from the main colony, a new community will be started nearer the source of supply by a migration of part of the former colony along the trail established. This expansion of the colony usually occurs in the early spring and summer months. In the late fall (November) the outpost communities are usually abandoned and large central winter colonies are formed in more favorable locations having better drainage and sun exposures. The activities in these communities are limited, fewer workers are sent out in search of food, the male form disappears, reproduction almost ceases, and the number of ants is reduced. Several colonies dug up in December, 1919, and January, 1920, showed a large number of workers in the colony with only a light trail going out in search of food, a number of females, no males, few if any eggs, a few matured larvæ, and numbers of pupæ. Renewed activities in these colonies and the division of the central colony usually occur in early April, though the time may vary somewhat with the season.

As stated, the summer colony is composed of three distinct forms of adults—workers, males, and queens. (See fig. 3.) The workers gather the food and attend to the labors of the community and are simply imperfect females with no reproductive capacity. They greatly outnumber the other forms and are the ones most commonly met with. The males, always winged, are the drones of the colony and have only one function, that of fertilizing the queen. The queens are the reproducing females and for a short time during the mating period are winged. They remain in the nest most of the time, but occasionally may be found out in the trails—a characteristic of this species (fig. 4). It is absolutely necessary that a fertilized queen accompany a number of workers if a new colony is to be established, as the workers alone have no means of reproduction.

The winters in southern California, though occasionally wet enough to retard the development of the ant colonies and force them to winter quarters, are so often broken by short, warm spells and the average rainfall is so light that trap nesting has proved ineffective and seldom are any of the colonies destroyed by excessive moisture.

The preferred food of the ants in orchards is the honeydew secreted by certain scales and aphids, the honeydew from blossoms, and the bodies of certain soft-bodied insects. The workers are very active in collecting this food and may be observed returning along the trail from a foraging expedition, their abdomens greatly distended with liquid food, or their strong mandibles securely clasping their prey. About residences the ants are more or less scavengers, feeding on bits of food wherever they can find it, but frequently invading pantries and even ice chests in search of meats, sugar, sirups, fruit, etc. Their trails may be extended to any part of the building in search of food and often during the first few hot days of summer the ants storm the house.

An interesting feature in the distribution of this ant is that it has completely replaced all native species, with possibly two exceptions, wherever it has become established. Only on the margins of the Argentine ant infestations does one find colonies of the native Prenolepis, Formica, and others. They have repeatedly been observed to dislodge the large red agricultural ant (*Pogonomyrmex californicus* Buckley) from its nest, though sometimes this species persists for a

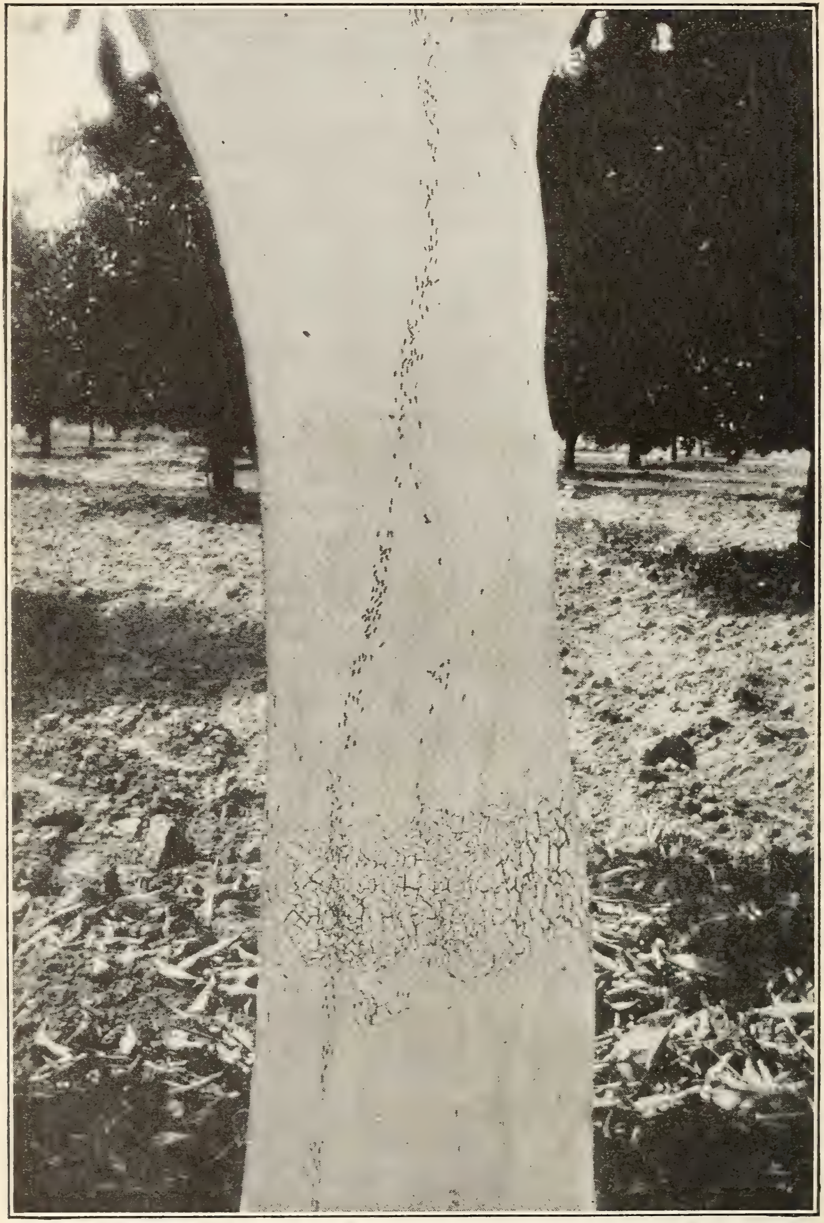

FIG. 4.—Characteristic trails of the Argentine ant on a tree trunk.

considerable period. Often after the Argentine ant has been eradicated in an orchard by control means the native ants will come in, but gradually the area will be retaken by the imported ant unless prevented. In comparison to this it is interesting to note the social habits of Argentine ants among themselves. They do not fight one another nor do members of different colonies disagree. In fact, trails from different colonies often converge and an interchange of workers may take place.

The workers are active throughout the day and night and feed almost continuously if not affected by temperature conditions. On cool, foggy, or frosty mornings with a temperature below 50° F. the activity of the ants is greatly retarded and they become slow and sluggish in their movements. Small colonies become almost inactive. Only a small percentage of the workers leave the colony to forage, the majority remaining to protect and care for the ant nest.

CONTROL.

The development and spread of the Argentine ant appear to be governed very largely by food supply and meteorological conditions. From natural enemies such as exert a restraining influence on most injurious insects this species is remarkably free and no record of even temporary control by this means has come to notice in the history of the pest in this country. Therefore, artificial control is the one source of relief once the ant has become established.

The first efforts toward control of the Argentine ant on citrus trees in southern California were made in July, 1915, and confined to banding with commercial sticky tree-banding material, a substance widely used to prevent insects ascending plants. Further experiments in repressive measures, including the use of the sticky material compounded with other substances, banding with corrosive-sublimate tape, and the use of pyrethrum and sodium fluorid, were carried on until the appearance, during the latter part of 1916, of Bulletin 377 of this department, by E. R. Barber, which presented for the first time a successful method of ant eradication. The superiority of eradication over control by repressive measures was immediately apparent, and subsequent experiments have been carried out with this in mind.

BANDING.

Sticky Tree-Banding Material.

EXPERIMENT 1.

During the latter part of September, 1915, an experiment with sticky tree-banding material was started in an orchard of 1,135 trees, each of which was attended by heavy trails of ants. Bands 3½ to 5 inches in width were applied directly to the trunks and the ants above the bands removed by the use of insecticides. Inspections were made at least biweekly for a period of six weeks following the start of the experiment and these bands were refreshened at the time of inspection and the ants removed from the body of the tree. During the course of the experiment upward of 70 per cent of the trees became reinfested. The cost for labor and materials to keep the ants in this 10-acre orchard under control by the use of bands amounted to approximately 15½ cents per tree, proportioned as follows:

Labor for pruning and banding 1,135 trees	$75.00
Sticky tree-banding material	22.80
Labor for inspection and treatment for ants	60.00
Material for ant treatment	10.00
Hand pump	10.00
Total cost	177.80
Cost per tree	0.156

It was quickly determined that constant surveillance and frequent combing of these sticky bands are necessary to keep trees free of ants.

EXPERIMENT 2.

Another experiment was performed, in which 120 orange trees were banded with sticky tree-banding material February 21–25, 1916, after the method used in Experiment 1. The ants were present in very light trails, due to retarded development during the winter months. This experiment was inspected weekly for a period of four months, at each visit the bands being refreshened where necessary, infested trees freed of ants, and all growth beneath the tree removed. The results of this inspection are given beneath.

	Per cent of bands crossed.
March	37
April	5
May	10
June	14

The bands in this second experiment proved decidedly more effective than those in Experiment 1. This is attributable to several causes. The work was started at a time when the weather was cool and the ants not numerous. In fact they were not abundant at any time during the experiment with the exception of a very few trees on which the bands were not continuously effective. Colonies were removed to neighboring trees where food was abundant and, furthermore, the bands were continuously in a good state of repair. Experiment 1 was started in September when the ants were steadily streaming up every tree to attend heavy infestations of mealybugs.

The size of the orchard prevented each band receiving the same careful attention given in Experiment 2. Instances were noted during the autumn where the bands on slightly attended trees were bridged within an hour following the application.

CONCLUSIONS.

The conclusion to be reached from these two experiments is that the constant attention required to make sticky tree-banding material an effective barrier to ants on heavily infested citrus trees renders the method impracticable in orchard work. It might be used to advantage on a few trees which can be given the necessary attention, as, for instance, on house lots or about buildings.

The general belief that sticky tree-banding material is injurious to citrus trees when applied directly to the bark has been found erroneous. The writers have never seen a citrus tree killed as a result of this treatment. In 1915, 40 three-year-old nursery trees were banded. Examination of the bark beneath the bands one year after application showed the bark perfectly green and healthy. The sticky material on 100 trees banded in September, 1915, was scraped off in July, 1916. In no instance was there certainty of injury to the bark or cambium. Examination of hundreds of trees which have been banded with sticky material for periods ranging from 1 to 5 years have failed to show definitely a single instance of severe injury attributable to the bands. A disease known as gummosis is prevalent throughout southern California especially on heavy soils. Exudation of gum from this disease, beneath the bands or closely adjacent, and the accompanying diseased tissues revealed by removing the band, have been sometimes attributed to the banding with sticky material, although no cases have been observed where this was definitely the cause. Applications to trees soon soften the bark beneath somewhat. After about one year the exposed surface of the sticky material becomes glazed and by the second year a hard exterior coating is found and only the substance adjacent to the tree remains moist and sticky. In due time, depending on the thickness of the sticky layer, the entire band becomes hard, and subsequently is broken by the expanding growth of the trunk. The bark where exposed to the air dries and assumes its normal consistency and appearance. Heavy bands may require several years to dry.

Possible injury from sticky tree-banding material might arise from removal of heavy bands within a year following their application or before they are somewhat dried out. In one case trees heavily banded in September were scraped the following July. The bark was so injured by the workmen in removing the sticky material that a very weak solution of corrosive sublimate was used to disinfect the wounds. The ultimate effect was such rapid drying of the scraped tissues that great flakes of bark peeled off, temporarily injuring the trees, although they soon recovered. When sticky bands are to be removed, therefore, this should be done without scraping the bark and the thin film will assure gradual drying of the bark without subsequent injury.

AXLEGREASE AND STICKY TREE-BANDING MATERIAL.

A mixture compounded of 1 part of ordinary black axlegrease and 2 to 3 parts of sticky tree-banding material recommended by J. R. Horton[4] was tried on a large number of trees in different localities. This material proved inferior to undiluted sticky material. A few hot, dry days in summer usually caused sufficient hardening of the surface for the ants thereafter to cross at will.

SULPHUR AND STICKY TREE-BANDING MATERIAL.

By far the most satisfactory "tree-sticky" substance tried was a mixture of sulphur and commercial sticky tree-banding material in the following proportions:[5]

Finely pulverized flowers of sulphur .... parts by weight..	1
Commercial sticky tree-banding material .... parts by weight..	6

The two materials should be thoroughly mixed until of a uniform consistency. In small quantities this should be done with a wooden paddle, although for large amounts that method is too slow and costly. The most satisfactory method observed by the writers for preparing large batches was a turning machine such as a lathe to which was attached a large corkscrew arrangement. A gallon pail partly filled with the proper proportions of ingredients could be mixed to proper consistency in a few minutes and with little effort. The attempt of one orchardist using a shovel to prepare the mixture in 100-pound lots naturally gave a very unsatisfactory mixture, with the sulphur in lumps, rather than a smooth, consistent mass as desired.

After preliminary experiments had proved that the bands of sulphur and sticky material were superior to all other tree-banding materials used, they were given a very extensive tryout over two seasons under widely differing climatic conditions. The results were variable. In one experiment in which 42 large trees had a heavy 5-inch band applied May 1, only 2 had been crossed by August 14, a period of 3½ months. Three adjacent plots comprising a total of 208 trees, for the most part with limbs 3 to 4 inches in diameter, were treated with bands 2 to 2½ inches wide. From 18 to 34 per cent of these bands were crossed within one month. In another case of several hundred trees banded with a poorly prepared material, showing granules of free sulphur, a very large proportion of the bands were crossed within a few days following the application. Experience has shown that heavy 4 to 5 inch bands of a mixture of sulphur and sticky banding material thoroughly protected from the sun will keep in good sticky condition during dry weather for a period of 2 to 3 months, or even longer. If exposed to the sun at all, a dry film quickly forms and the ants cross at will. Furthermore, the direct sun causes the material to become very soft and to run down the trunk.

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[4] HORTON, J. R. SOME WEATHERPROOF BANDS FOR USE AGAINST ANTS. *In* Calif. State Comm. Hort. Monthly Bul., v. 5, no. 11, p. 420. 1916.

[5] HORTON, J. R. Op. cit.

Although there is no particular reason why the addition of sulphur should cause the sticky material to be injurious to the bark of a tree the precaution was taken in all our experimental work to apply first a protective substance. (See fig. 5.) At first 3 to 4 inch bands of oilcloth were applied to tree trunks by means of adhesive tape attached to the upper and lower surfaces, and the tree-banding substance was applied to this band. The difficulty experienced in covering irregular tree trunks with such bands led to search for an innocuous substance that could be painted onto the trunk and the most satisfactory material tried was paraffin. This was first melted and kept at a temperature just above the melting point when applied to the tree trunk. A paint brush proved satisfactory for the work. The paraffin under no circumstances should be at a very high temperature, else it will penetrate deeply into the bark. The requirement is a superficial layer. While the ordinary grade of paraffin recommended for home canning proved satisfactory in thoroughly shaded trees in the coastal districts, in the warm interior valleys, on tree trunks sometimes reached by the sun, they melted on the sunward side and deeply penetrated the bark, causing considerable injury. This necessitated the use of a paraffin with high melting point, one exceeding 130° F. Such paraffins are purchasable of oil-refining companies or dealers in technical supplies. *The caution should be observed, however, that under no circumstances should trees be banded with sulphur and tree-banding sticky material over a paraffin band in situations reached by the direct sun.*

COST.

In 1916 the average cost per tree banded with this mixture was 7 to 8 cents, exclusive of removing the weeds beneath the trees and pruning the branches. At present the cost would approximate 15 cents.

Pyrethrum and Sodium Fluorid.

Sodium fluorid and pyrethrum were used singly or in mixtures and applied to the crotches of trees or on cotton bands around the trunks. (See fig. 6.) The cotton bands usually rid the trees quickly

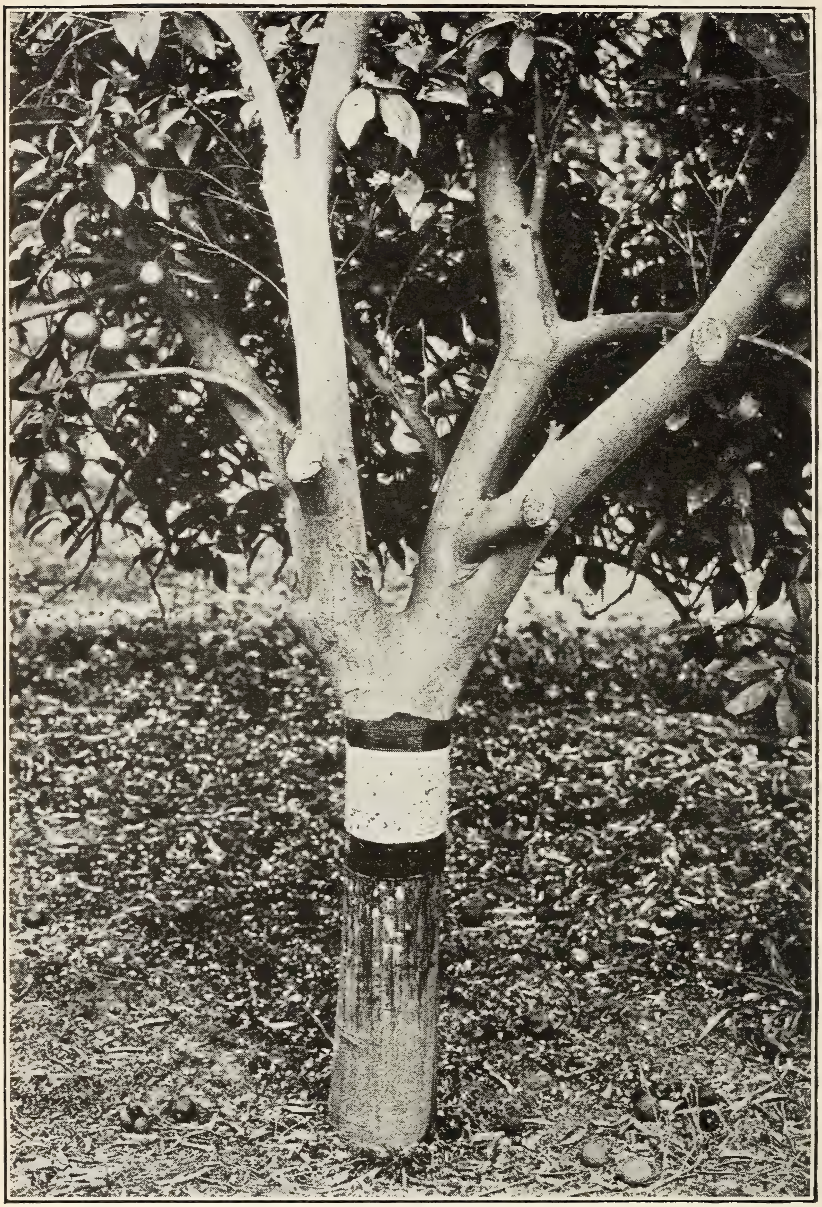

FIG. 5.—Keeping ants off citrus trees. A 5-inch band of sulphur and commercial sticky tree-banding material over a wider coating of paraffin. (Woglum and Neuls.)

of ants but their effectiveness was lost upon exposure to the weather. Once wet these insecticides are valueless. These powders, especially the pyrethrum, singly or in combination with the sodium fluorid, are decidedly repellent to ants and quickly cause death once they come well in contact with their bodies. The fact that their strength is soon lost on exposure to air restricts their usefulness.

The following experiments demonstrate the comparative efficiency of these substances used singly or in combination. Breeding cages containing a large amount of mealybug-infested lemons and potato sprouts were heavily attended by ants which entered in steady streams along the legs. The legs were set in tops of fruit jars containing a small amount of sodium fluorid powder. Ants continued to cross in limited numbers for about one hour before the trails were completely broken up. No dead ants were found.

Pyrethrum powder was sprinkled about the legs of one cage, stopping the trails almost immediately. Dead ants began to pile up in the powder and on the floor about the powder.

A mixture containing pyrethrum 1 part, sodium fluorid 7 parts, and plaster of Paris 2 parts, was dusted about the legs of a breeding cage attended by ants with effects about as satisfactory as with pyrethrum alone.

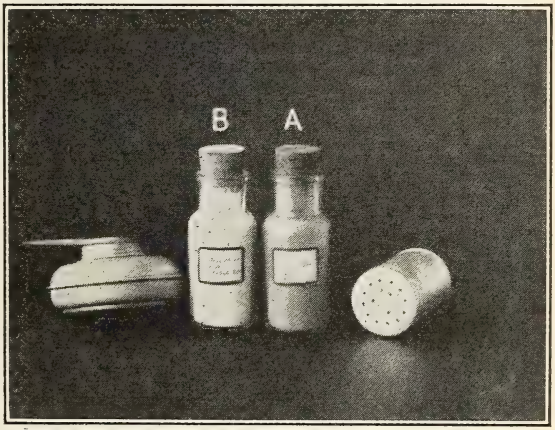

FIG. 6.—Repellent ant powders: *a*, Pyrethrum: *b*, pyrethrum 30 per cent, sodium fluorid 70 per cent. Shaker and blower for applying.

CORROSIVE SUBLIMATE ANT BANDS

Corrosive sublimate has long been known to possess merit as a repellent to ants and this fact has been utilized in protecting materials from these pests. A common method is to soak narrow strips of cloth in a saturated solution of this chemical and use these as barriers. The saturated solution is best prepared by heating about 1½ ounces of corrosive sublimate in an ounce of water until the maximum amount is dissolved. The solution is then allowed to cool, is filtered, and the cotton band or tape is soaked in it for several hours. The tape is then removed, allowed to dry, and is ready for use. This amount of solution is sufficient for from 10 to 12 yards of ¾-inch tape.

Several small nursery trees infested with the cottony-cushion scale, *Icerya purchasi* Maskell, attended by ants, were banded with such tape to determine its effectiveness against the ants, as well as its effects on the trees. The trees were quickly freed of ants and remained so throughout the experiment. The tape, however, soon killed the bark down to the wood and the trees ultimately died.

Fourteen large orange trees were banded with mercuric bichlorid ant tape on September 10, 1915, the tape being wound around the tree several times to form a band several inches wide. The bark was protected from the band by heavy paper. On October 10, one month after the bands were placed, an inspection showed that 5 of the 14 bands had been crossed. These had been rendered ineffective by heavy fogs.

The great danger attendant upon the use of corrosive sublimate, its ineffectiveness when exposed to moisture, and its high cost render this substance generally impractical for repelling ants. It is, however, of special value for protecting apiaries which are seriously troubled by this pest. Newell and Barber,[6] working in Louisiana, invented a four-legged hive stand from which they were able to keep the ants for many months by winding ant tape about the legs. The writers have tried a similar stand under California conditions with success, even where honey and other substances attractive to ants were profusely scattered over the top. Equally satisfactory with the ant tapes was found a mixture of mercuric bichlorid and shellac which could be applied directly with a brush. A formula adapted from Horton [7] consists of:

Corrosive sublimate	gm..20	or oz..¾.
Alcohol	cc...60	or oz..2.
Shellac	gm..31	or oz..1.

The corrosive sublimate is first dissolved in the alcohol, then the shellac added, and the mixture shaken until all is dissolved.

Freeing Trees of Ants After Banding.

Freeing trees of ants after banding is an essential part of tree isolation. Heavy infestations of ants at the time of banding will sometimes form a crossing over bands of sticky material from the accumulation of entangled bodies of ants which have attempted to escape from the tree. With corrosive sublimate or ant powders such attempted crossing in no way affects the efficiency of the bands; in fact, on such banded trees ants usually drop off before making an attempted crossing and the trees become free of ants unless colonies are already present in cracks or accumulations of débris in the crotches. Many large trees support aerial colonies during the warm season and not infrequently colonies have been noted in midwinter.

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[6] Newell, Wilmon, and Barber, T. C. Op. cit., p. 88–91, figs. 11–13, Pl. VII.

[7] Horton, J. R. The Argentine Ant in Relation to Citrus Groves. U. S. Dept. Agr., Bul. 647, p. 64. 1918.

Several methods of freeing banded trees were tried. The first method was to spray the trunk and main branches with such insecticides as carbolic-acid emulsion or distillate emulsion immediately after banding, the application being made with a compressed-air pump holding 3 gallons. This proved too slow and ineffective, as ants are actively engaged throughout the tree during the day. It was soon observed that the early morning was the proper time to destroy the ants above the bands, for they are sluggish at the cool temperatures and have the habit of congregating in crotches or in their aerial nests. The compressed-air pump was soon discarded in favor of a plumber's hand torch (fig. 7), in which gasoline or a weak cyanid solution was used as a spray. This in turn gave way to the use of pyrethrum or other ant powders which proved simple of application, economical, and immediately effective. Nests in tree crotches or elsewhere could be quickly freed by a single application, and for this purpose either a small bellows or shaker (fig. 6) proved satisfactory.

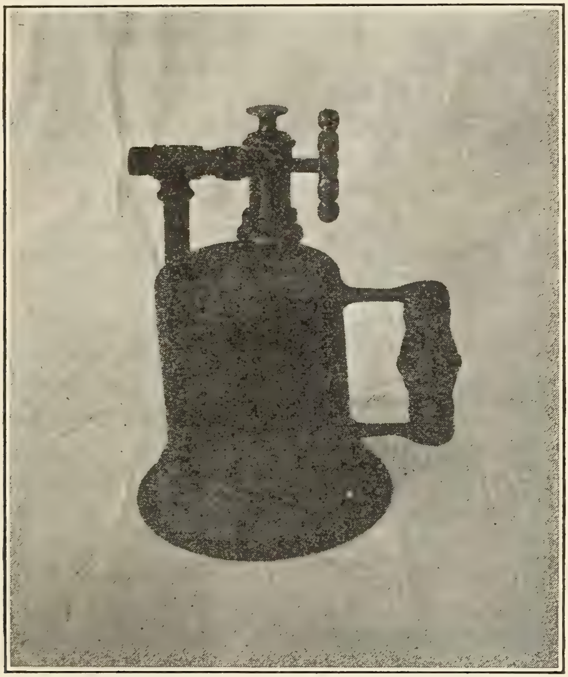

FIG. 7.—Plumber's torch for applying certain sprays to rid a banded tree of ants.

Summary of Use of Repellents.

Although the writers' experience with banding demonstrated that trees could be kept freed of ants by careful and diligent effort, it was apparent that the constant attention needed for success would not be forthcoming where large acreages were concerned. Furthermore, the method of pruning followed in some orchards produces trees so low that growers seriously object to removal of the large amount of growth necessary for tree isolation except at the trunk. Even after pruning the increasing weight of the fruit weighs down the branches and cultivation frequently breaks small twigs which demand additional attention. Grass and weeds quickly spring up beneath the trees and in contact with a tree leaf furnish a bridge which is invariably discovered by the ants. In fact the ants may find access to a tree by way of a blade of grass which comes in contact with a leaf of the tree momentarily stirred by the wind. In one case a branch of a banded tree rested against a telephone pole and gave a means of reaching the tree. The branch was pruned and the telephone pole banded, yet the infestation persisted. It was finally discovered that the ants crawled along a guide wire to the top of the telephone pole, and thence down to a part where a single leaf momentarily touched the pole as moved by the wind. This was the signal for the persistent little pests quickly to mount the leaf while others moved to the pole.

The glazing of sticky bands where exposed to the sun, the accumulation of falling petals during the blossoming season, the spattering of dust over the bands during rains, or the washing down of dust, leaves, broken twigs, and the materials collected during heavy windstorms, all contribute to render banding with adhesive mixtures impractical over large acreages. In spite of all these drawbacks bands can be made to serve a useful purpose on limited numbers of trees, especially about yards where necessary attention and renewal or respreading can be given. It should be borne in mind, however, that banding merely repels without destroying ants, and destruction is what is actually required.

TRAP NESTING.

The discovery that large boxes filled with decaying vegetable matter would attract ants in numbers in winter induced Newell and Barber to try this plan in infested orange orchards in Louisiana, and their efforts were reputed to have met with great success in reducing the infestations. The trap boxes were subsequently fumigated and the ants destroyed. Horton[8] also recommended the use of trap nests as by far the best and most practical means of destroying the Argentine ant in the orange groves of Louisiana. The great success attending this method in the Southeast induced the writers to conduct an experiment under the more arid conditions in the Southwest.

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[8] Horton, J. R. CONTROL OF THE ARGENTINE ANT IN ORANGE GROVES. U. S. Dept. Agr., Farmers' Bul. 928, p. 12–16. 1918.

A 10-acre orange grove at Upland, Calif., very severely infested with Argentine ants, was selected for the experiment. Five-gallon tin coal-oil cans (9¼ by 9¼ by 13½ inches) were used for traps (see fig. 8), being much cheaper than the wooden boxes, and affording complete protection from rain or winds. One end was cut along three sides and this acted as a flap over the entrance of the can, protecting it from beating rains. Three hundred and fifty cans were used, being divided into seven lots of 50, each lot containing a different filler. These were respectively green grass and dirt, green grass, green alfalfa, dry straw, wet straw, moist dirt, dirt, and leaf mulch. The cans were placed on a side, close up to the base of the tree. Approximately 3 of the 10 acres were reserved as a check, the remaining 7 being covered with ant traps, one to each tree on about 3 acres and one to every other tree on the remainder. These were placed December 1, 1917.

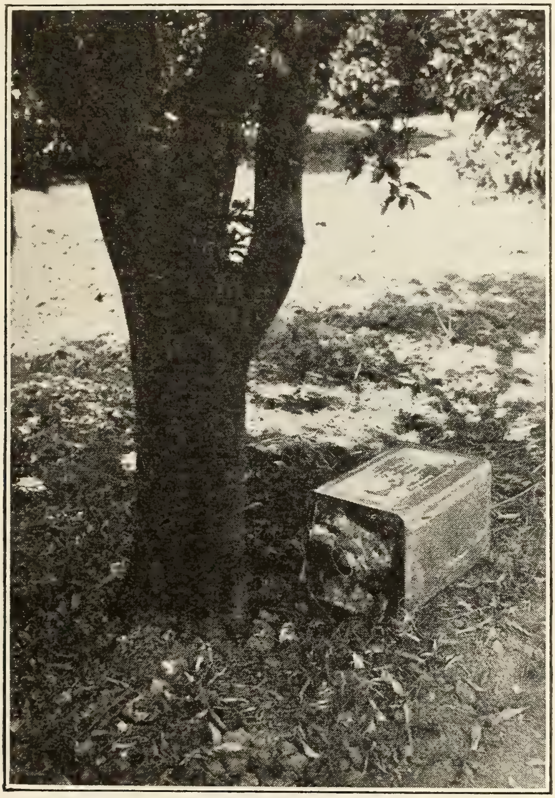

FIG. 8.—Winter trap nest, consisting of 5-gallon oil cans filled with nesting material, in place at base of tree.

An inspection February 7, 1918, showed that some ants had colonized in the cans, but in the absence of heavy rains the ants were continuing largely in their ground colonies. A final inspection March 18, 1918, showed that only 41 per cent of the cans contained nests, and these were for the most part small. Many colonies were found in the ground beneath the cans or even at the base of the trees near the cans; in fact, in all cases the preponderance of ants in the orchard appeared to be outside the cans. The cans were fumigated with carbon disulphid immediately following the final inspection. An inspection of the entire grove in May showed the ants as prevalent in the part over which ant traps were distributed as in the check plot, thus demonstrating the futility of ant control in California by the trap-nest method recommended for Louisiana.

A second experiment in an adjacent grove with 50 trap boxes during the same winter gave no better results.

The success of trap nesting, as pointed out by Newell and Barber, depends upon rainy weather. The winter of 1917–18 was a warm and open one with light rains, and this resulted in ants being more or less active in southern California throughout the season. It is very probable that in a colder winter with heavy rains trap nests would be more successful. Even under the most ideal conditions for trap nesting, however, this method would be less effective and more costly than the poisoned-sirup method later taken up in this publication.

POISONED SIRUPS.

Eradication is the ideal to be sought with any pest and particularly does this apply to the Argentine ant. Once the ant is eliminated from a grove, future effort can be restricted to protecting the borders from invasion from neighboring property. The most effective method of eradication tried in California has been the use of a poisoned sirup, which is eaten by the ants. For the most part arsenic in some form constitutes the toxic substance of such a poison, although a few nonarsenicals have been used.

In all orchard work small containers of tin or paraffined paper were used, partly filled with sirup and hung one to a tree, the ants entering through small holes in the sides.

CHLORAL HYDRATE.

Chloral hydrate was recommended by Horton[9] as the best poison for orchard use. It is prepared as follows:

> Make a sirup by stirring 8 pounds of granulated sugar in one-half gallon of cold water until dissolved, making 1½ gallons of sirup. Then add 4½ ounces of chloral-

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[9] HORTON, J. R. CONTROL OF THE ARGENTINE ANT IN ORANGE GROVES. U. S. Dept. Agr., Farmers' Bul. 928, p. 19. 1918.

hydrate crystals, previously dissolved in a small quantity of water, and about one-half pound of strained honey.

On July 22, 1918, an orchard experiment was started in which 2-ounce spice tins about one-third filled with chloral-hydrate sirup according to the foregoing formula were hung on 48 trees attended by heavy trails of ants. The ants fed on this sirup greedily when first distributed and continued feeding freely throughout the duration of the experiment, which was five months. The sirup started crystallizing about one month after being distributed and within six weeks most of the containers were partly filled with large crystals resembling rock candy. Although the sirup proved attractive, it did not appear to reduce the numbers of ants more rapidly than they bred, for ants were almost as numerous at the completion of the experiment as at the beginning. The tendency of this sirup to crystallize and its only partial action against ants show it to be not fully satisfactory as a poison.

Arsenical Poisons.

Arsenic in large quantities acts as a repellent to ants and its earliest use against the Argentine species was based on this action. Woodworth, experimenting later with this insect in the San Francisco Bay region of California, obtained success in control by the use of an unboiled sweetened poisoned sirup containing about one-fourth of 1 per cent of sodium arsenite.

In 1916 E. R. Barber[10] published the results of his efforts against the ant in Louisiana with an improved arsenical sirup and showed for the first time that eradication was possible over extensive areas. This system immediately appealed to the senior writer as offering a more practical solution of the ant problem in California than banding, which he had previously been using, and accordingly an experiment in controlling the ants about the laboratory was started in October, 1916, and met with marked success. In December, 1916, an orchardist, who had observed the effectiveness of the system installed on the laboratory grounds, attempted control on his property by this method. This was the first control attempted in southern California in a citrus orchard. Others were thereupon induced to adopt the methods which Mr. Barber had proved eminently successful in Louisiana, and at the same time the writers started an investigation of the use of this poison under California conditions. This led to experimenting with various other formulas containing arsenic as the basic poison and the ultimate development of a formula thoroughly satisfactory under California conditions.

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[10] BARBER, ERNEST R. THE ARGENTINE ANT: DISTRIBUTION AND CONTROL IN THE UNITED STATES. U. S. Dept. Agr., Bul. 377. 23 p., 5 fig. 1916.

ORIGINAL BARBER FORMULA.

Orchard A. The owner of a 10-acre orchard of large Valencia and navel orange trees located at Alhambra in a district overrun with the Argentine ant was induced to attempt control by the use of the poisoned sirup which had proved so successful in Louisiana. This work was done under contract and the poison prepared according to the original Barber formula as follows:

Granulated sugar	pounds	15
Tartaric acid (crystallized)	ounce	$\frac{1}{4}$
Sodium arsenite C. P	do	$\frac{3}{4}$
Honey	pounds	$1\frac{1}{2}$
Water	pints	8

A special 1-pound paraffined paper sack punched with a few small holes and containing about an ounce of sirup and a 1-inch cube of sponge was attached to each tree, either on the trunk or one of the main branches. The orchard was in a state of clean cultivation with no grass or weeds beneath the trees, and in most cases the lower limbs were entirely free of the ground, so that the trunk formed the only means of access to the tree for the ants. The distribution of filled containers was made on May 14–15, 1917. No inspection was made at the time of sirup distribution, although during the previous autumn trails of ants were present on every tree, and a careful examination in April showed heavy streams of ants on trees in all parts of the orchard.

Some of the paper bags lost their contents soon after distribution and these were replaced in the latter part of June. The sirup thickened rapidly during the summer and by the first of August, or probably two months after the experiment was started, the contents of many bags had commenced to crystallize or solidify. When this stage was reached, it was noted that the sirup no longer proved so attractive to ants. A few bags were refilled in August, and in September fresh sirup was placed in all containers.

After the sirup was distributed frequent inspections of this orchard were made throughout the season of ant activity and notes taken on the progress of the control and eradication. These results were most encouraging and showed conclusively not only that orchard control of the ant was possible, but that the ant could be eradicated by persistent effort.

The experiment began on May 14, with most of the trees in the orchard heavily attended by trails of ants; by May 22, or within a week's time, these had been reduced to only 26 per cent with trails; and within two weeks to 11 per cent. By July 19, or two months after the poison was distributed, the ants had either been entirely destroyed or reduced to within the limits of control on 98 per cent of the trees in the orchard. With the approach of the middle of August the ants were practically controlled throughout the orchard.

Progress (fig. 9) is naturally slower from the standpoint of eradication than of control. For the first month eradication of ants from trees was constant and rapid, 52 per cent of the entire orchard being freed within this time. Then eradication slackened and for the succeeding 6 weeks made no noticeable gains. By the middle of August an increased number of trees were free of ants and this continued until by the middle of November ants had been eradicated from 92 per cent of the trees, those remaining being mostly marginal and attended by a few stragglers from adjacent property.

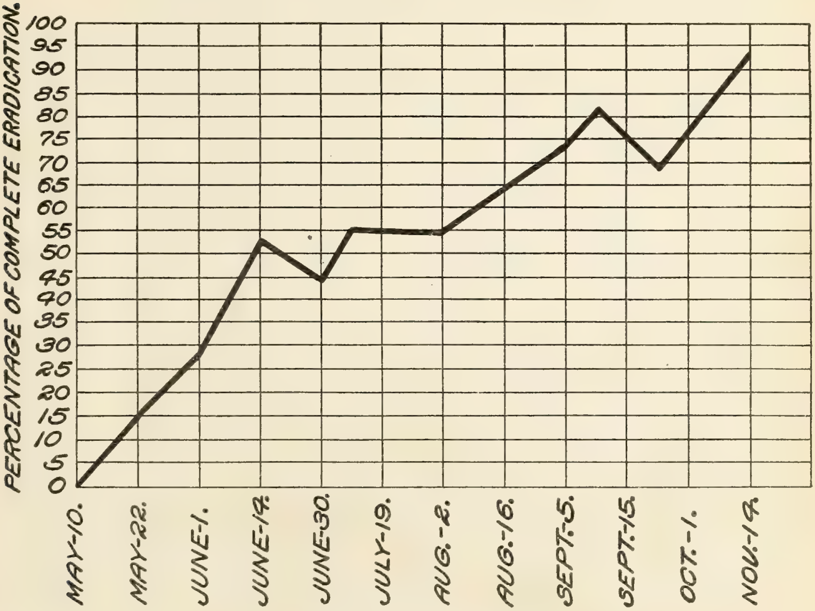

FIG. 9.—Progress of ant eradication on a 10-acre citrus orchard.

It should be noted in presenting the marked success of this experiment that the trees were quite free of scales, although a few mealybugs were present. Therefore the food supply was not particularly abundant. Likewise worthy of note is the fact that this orchard had been severely infested with *Pseudococcus citri* for four years prior to ant control but since then this pest has been effectively controlled by its natural enemies.

TABLE 1.—*Effectiveness of Barber poisoned sirup in the control of the Argentine ant in a citrus orchard.*

	Dates of inspections.										
	May 22.	June 1.	June 14.	June 30.	July 19.	Aug. 2.	Aug. 16.	Sept. 5.	Sept. 15.	Oct. 1.	Nov. 14.
	P. ct	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Free of ants	15	28	52	44	55	54	63	72	81	69	92
Trails of ants	26	11	11	4	2	1	¼	¼	0	¼	0
Few straggling ants	59	61	37	52	43	45	36	27	19	30	8
Either free of ants or with few stragglers only	74	89	89	96	98	99	99	99	100	99	100

Orchard B, located at Upland, Calif., consisted of 6 acres of Valencias and 4 acres of naval oranges, with a total of 674 trees. They were very large, being about 25 years old, and quite severely infested with the citrophilus mealybug. The lower limbs which rested on the ground were trimmed up, thereby forcing the ants to ascend the trunks. The orchard was in a clean state of cultivation with no vegetation growing beneath the trees. The ant sirup was prepared according to the original Barber formula and put out in 1-pound paraffined paper bags, one to each tree as described in orchard A. The distribution of the sirup was completed October 5, 1917. A careful inspection was made from time to time to note the stability of the sirup and its effectiveness against the ants. Some crystallization appeared within 6 weeks, and by the end of the second month practically all had hardened. The ants fed heavily on the sirup before crystallization took place and their numbers became greatly reduced during the autumn months. Although prior to the sirup distribution only 5 of the 674 trees were free of ants, all the remainder being attended by trails of ants, many having two or even three trails along the trunk, these trails became weaker and weaker and were almost broken by the time the sirup began to crystallize.

There was slight ant activity throughout the winter, due to the open season. On March 3 and 4, 1918, an inspection of the orchard showed above 99 per cent of the trees entirely free of ants, only 3 of the 674 trees being infested. By April 9 ants had invaded the orchard from severely infested adjoining territory, so that 26 trees were infested. Fresh sirup was distributed on these trees at this time, and on June 17 on other marginal infested trees. By June 29 ants had been eradicated from 672 of the 674 trees in the orchard, and the experiment stood as a determination of the efficiency of the poisoned-sirup method in orchard eradication of ants.

Cost.—The cost of ant eradication in these 10 acres, including the materials, labor in preparation, and distribution of 674 containers in October, 26 in April, and 32 in June (a total of 732), amounted to $19.03, or 2.6 cents per tree.

Crystallization.—The sirup prepared with the formula used in orchards A and B commenced to thicken in from two to four weeks after its distribution in the orchard and crystallization started in from six weeks to two months. Sirup distributed in the dry cold weather of late fall was observed to crystallize in some cases within a month. The sirup proved less attractive to ants as it thickened, and crystallized sirup was little attended. Although the Barber formula proved very effective against the ants under conditions where heavy feeding followed the initial distribution, and control was really effected during the period of normal stability of the sirup, as was the case in orchards A and B, weather conditions and normal food supply of the ants frequently were such that feeding was slight during the early weeks of distribution. If in such cases the sirup became crystallized within a month or six weeks following the distribution its effectiveness against the ants was greatly reduced.

The situation is well presented by the comparison of ant control in a 10-acre orchard adjacent to orchard B, at Upland. The orchard consisted of 676 trees, 76 of which were reserved for control by another system. Ant control by the same sirup as used in orchard B was started in the remaining 600 trees, which were largely navel oranges with ant infestation practically identical with that in orchard B. The distribution took place during the first part of November, or fully a month later than in orchard B, and the sirup crystallized within a month after being put out. Although above 99 per cent of the trees in orchard B were free of ants on March 24, 1918, in this latter orchard only 65 per cent were in this condition. The difference in control is attributable to a shorter period of sirup supply. This crystallization of sirup led to experiments in an effort to secure a sirup of greater stability and possibly more attractive to the ants.

MODIFIED BARBER FORMULA I.

Observations indicated that sirup which had become diluted by rain entering the container was more stable than the more concentrated sirup. This led to the use of a modified formula in which the sugar was reduced from 15 pounds to 12 and the honey increased by one-half pound to compensate for the reduced sweetness. Experiments with this sirup during 1918 proved it to be as attractive to ants as the original formula and its stability was greatly increased, for during the summer it remained without crystallizing for periods up to four months. This sirup was used over a great acreage during 1918 with marked success. With the approach of cold weather it was found that this sirup would crystallize, though much more slowly than the thicker sirup.

Unboiled sirup.—An experiment was started on 50 trees in which the modified Barber formula was prepared without boiling, the sugar being dissolved in lukewarm water, to which the dissolved arsenic and honey were then added. No tartaric acid was used, for an alkaline sirup, which might prove more attractive to ants, was desired. During the first week the ants fed more freely on the unboiled sirup than on the boiled sirup in an adjacent plot, and at the end of the first month both sirups proved equally attractive. The unboiled sirup then started to turn dark and decompose, after which its attractiveness to ants was greatly decreased. The boiled sirup, however, was in perfect condition at the end of the month and its attractiveness continued. This plainly shows that the unstability of an unboiled sirup renders it less useful than the boiled sirup.

Saccharin.—The shortage of sugar in 1918 led to experiments with substitutes, and of these saccharin, supposedly 600 times sweeter than sugar, was one of the first tried. A formula was prepared using three-fourths of an ounce of saccharin, 2 pounds of honey, and three-fourths of an ounce of sodium arsenite to 2 gallons of water. Three-fourths of an ounce of saccharin is equivalent to 28 pounds of sugar, and at this rate the sweetness of the sirup was approximately twice that of the regular Barber formula. This sirup was lightly attended by ants during the first few days following its distribution, but thereafter proved repellent. Other formulas were made containing decreased amounts of saccharin, but in all cases the sirup proved unattractive to the ants.

Glucose.—Glucose was used in several different formulas as a substitute for sugar. In no case did it prove as attractive or effective as the original or modified Barber formulas.

MODIFIED BARBER FORMULA AND CHLORAL HYDRATE.

A sugar sirup with chloral hydrate as the poison proved highly attractive to ants but did not possess the required killing properties. It was thought, therefore, that chloral hydrate added to the modified arsenical formula might increase the attractiveness of the latter to ants and result in their very rapid eradication. Accordingly, 3 ounces of chloral hydrate in solution was added to 1 gallon of the arsenical sirup and the mixture distributed in containers on ant-infested trees. The ants attended the cans slightly at first, but the sirup proved repellent. Other formulas with greatly reduced chloral hydrate proved equally repellent.

FINAL FORMULA.

The thickening of the sirup in modified Formula I during the summer and its frequent crystallization after protracted exposure to cold weather during the winter led to the preparation of a still more dilute ant sirup, in which 11 pints of water were used instead of 8 pints as previously. This new sirup was first prepared during the spring of

1918, and has since been used on more than 2,000 acres of citrus. It is of thin consistency and greater stability than Formula I. It has proved very attractive to ants and has been highly effective in control and eradication It was discovered, however, that fermentation of this more dilute sirup sometimes occurred, especially in the damper sections near the coast. This was corrected by the use of benzoate of soda at the rate of 0.1 per cent.

Preparation of final and most satisfactory formula.—The final formula was prepared as follows:

		Cost.
Water	11 pints	$0.000
Tartaric acid (crystallized)	7 grams	.016
Benzoate of soda	9 grams	.029
Granulated sugar	12 pounds	3.00
Honey, strained	2 pounds	.77
Sodium arsenite, C. P.	¾ ounce	.047

Total sirup, 2½ gallons. Cost per gallon, $1.54.[11]

Put 10 pints of water in a clean vessel over a low fire. When tepid add tartaric acid, then benzoate of soda, and then the sugar, slowly, while stirring to prevent burning. Measure the depth of the liquid with a stick. Slowly bring it to a boil and allow it to simmer for from 30 to 40 minutes. Remove from the stove and add water to compensate for evaporation. Stir in the honey before the mixture cools. Then add sodium arsenite which has been dissolved in 1 pint of hot water and partially cooled before being poured into the sirup. Stir thoroughly.

It is necessary that great care be exercised in the selection of the materials used, as well as in the preparation of the sirup. Either cane or beet sugar may be used. The sodium arsenite should be chemically pure. The honey should be strained and free of comb. The sodium arsenite preferably should be dissolved in distilled water to avoid the precipitation which sometimes occurs if very hard water is used. Vessels should be thoroughly cleaned before being used for the preparation of ant sirup, and it is desirable that they be used for this purpose only. Oils and various chemicals are distasteful or repellent to ants, and sirup which acquires a flavor of such substances from the container in which it is prepared or stored may be unattended by the ants. The stability of the sirup depends much upon the way it is boiled. If brought to a boil within a few minutes and boiled vigorously for 30 minutes the stability appears to be much less than if brought to a boil very slowly and then merely allowed to simmer for 30 or 40 minutes. Where several times the amount given in the formula is made in a large vessel the sirup appears to "stand up" best. This seems due to the fact that the sirup does not come to a boil for an hour or longer, and this probably results in greater inversion. The sirup should be used when fresh. Clean glass bottles are best if the sirup is to be stored.

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[11] With sugar at present prices (about 10 cents a pound) the cost would be only about 82 cents a gallon.

CONTAINERS.

BAGS.

One type of container extensively used was a $\frac{1}{4}$-pound paraffined paper bag (fig. 10.) Well-made paper bags were purchased in large quantities, punched about 2 inches above the bottom with four holes small enough to exclude honeybees, and dipped in molten paraffin of a melting point above 124° F. Paraffin, being highly inflammable, should be removed from the stove during the dipping. The top of the bag is held with a pair of curved forceps or pliers, the bag completely submerged in the paraffin, momentarily drained, and stood top upward on a greased board or tin. This allows the residue paraffin to settle well into the bottom, the part where leakage is most apt to occur. Bags were found to be quite satisfactory and the least

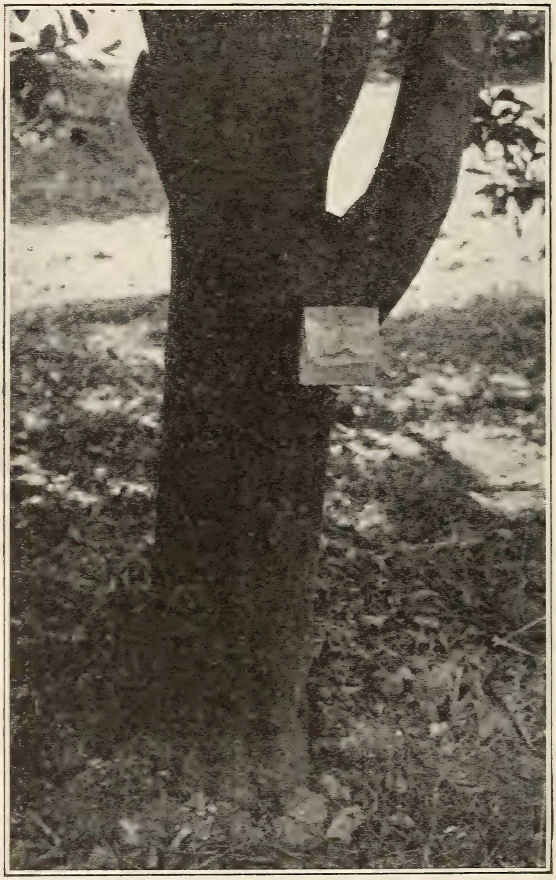


FIG. 10.—A paraffined paper bag in place on tree.

expensive of all containers. They have, however, certain drawbacks. They are prone to leak and wherever the arsenical sirup drips on the bark of a tree injury follows. Therefore it has been found advisable to hang paper sacks to the trunk or main branches so that no sirup will drip on the tree. During the rainy season the unprotected paraffined sacks as used in California collect water and do not stand up well. Ants, however, are for the most part inactive at that time, so control is seldom necessary during the winter. One great advantage of paper bags is that feeding by the ants or crystallization of sirup is quickly detected without removal and opening. Paraffined drinking cups or other paraffined containers on the market could be used in orchards for holding ant sirup.

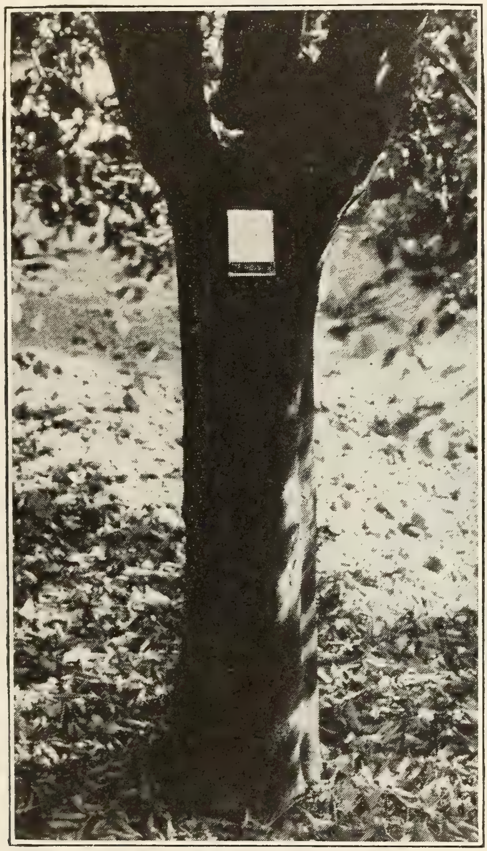


FIG. 11.—A paraffined spice tin on tree trunk.

CANS.

Sixteen-ounce round baking-powder tins recommended by Barber were tried in one orchard but proved too large and cumbersome. Several hundred 4 and 8 ounce tins of the same shape were used in experimental plots. These proved more satisfactory. In canvassing the market for different types of tins available in quantity at a reasonable price it was found that the 4-ounce oblong spice tin with plain cover (fig. 11) met the requirements most closely. Such tins are crimped without solderings and are not water-tight at the seams. It was found that dipping these cans in paraffin of high melting point covered both the inside and outside with a thin, almost invisible coating, prevented leaking, and rendered them rust-resistant. (Fig. 12.) One small hole was punched in a side about 1 inch below the top and the can hung by it on the tree over a 2d. finishing nail. These cans have proved the most satisfactory of all containers. They lie close to the trunks of the trees and are not moved by either wind or rain. When the ants are sluggish, as they are in cold weather, not uncommonly they cluster beneath the can and this doubtless increases their feeding.

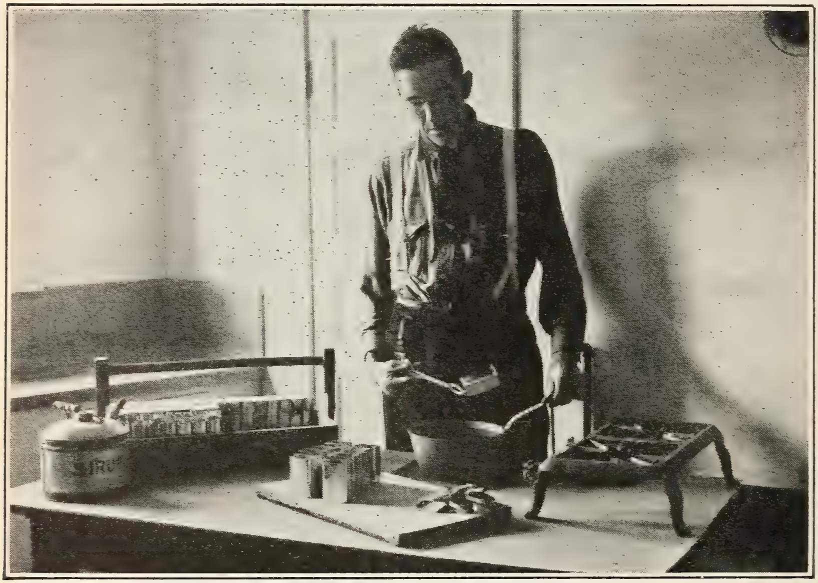


FIG. 12.—Method of paraffining spice tins for use in the field.

GROUND TRAPS.

In control work about houses, especially where there are large lawns, and also in conservatories where water is freely used, water-tight round cans are advantageous. These are set in the ground along the main runways of the ants. A small baking-powder can with friction cover indented in two or three places immediately beneath the cover to allow passage of ants would prove satisfactory. Such a can is being used in Louisiana. A very successful lawn trap used in California consists of a pimiento can protected by a special cover attached to a 6-inch stake. (Fig. 13.) A hole is made in the grass large enough for the can. The stick is then set into the ground until the cover fits firmly over the can. When these covers are painted foliage-green and sunk even with the grass they are inconspicuous. The lawn can be mowed or watered without destroying the sirup or container.

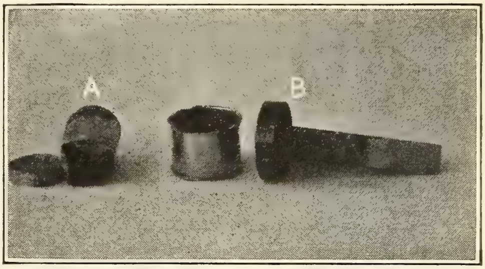


FIG. 13.—Types of ground traps: *a*, A small baking-powder tin with the edge bent to permit passage of ants; *b*, a special ground trap used in California for control about residences.

FILLING AND DISTRIBUTING CONTAINERS

It has been found most practical to fill the containers in the field. The cans or bags are prepared beforehand and taken into the orchard. These are arranged on trays as shown in figure 14. A gallon can with a long spout is handy for filling. In each container three-fourths to one inch of sirup is used and this in reality averages about 1½ ounces. At first small cubes of sponge were used in each can or bag to increase the feeding surface. It was soon discovered that the sponges hastened evaporation and thickening of the sirup and were thus a disadvantage rather than an asset. A very satisfactory substitute for the sponge was found in excelsior and four or five clean strands about a foot long were folded very loosely in the can or preferably suspended from the top, as shown in figure 15. Under no circumstances should a large, heavy, compact wad of excelsior be used. The advantage of the loose strands is that they furnish an attractive runway for the ants, reduce the likelihood of their

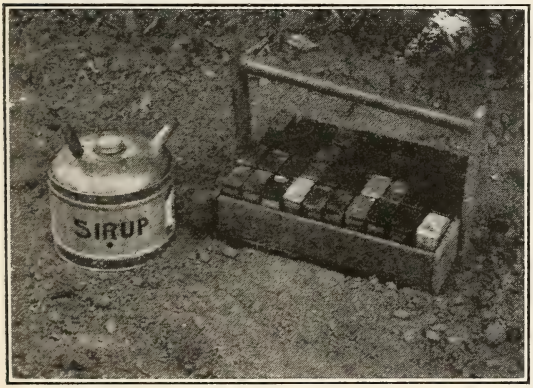


FIG. 14.—A convenient type of tray for field distribution of poison containers, and a 1-gallon can for holding poisoned sirup.

becoming entangled in the sirup, and at the same time increase the feeding area. When folded into a compact mass excelsior is unsatisfactory and tends to obstruct the free passage of ants, and furthermore absorbs much of the sirup unless the can is well filled. Excelsior has entirely displaced sponges in California.

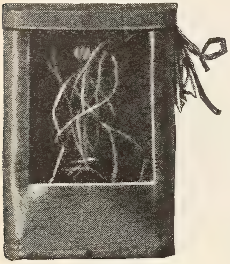


FIG. 15.—A spice tin with front removed to show amount and arrangement of excelsior.

After the spice tins or bags are filled, the tops are put on or the upper part of the bag folded, and they are then ready for attachment to the tree. (Fig. 11.) The bags are tacked as shown in figure 10. The cans are hung on a small finishing nail which is first driven into the tree. The containers should be on either the trunk or main branches on the shady side of the tree.

REFILLING.

The writers have practiced and advocate monthly inspections. A tray of filled containers should be carried along and where an empty, missing, or crystallized container is found it can be replaced. If crystallization is general all containers should be removed. Fresh sirup should never be poured onto that crystallized, as it has been found that normal sirup mixed with crystallized sirup quickly hardens. Where bags are used they can be discarded for new ones. Crystallized sirup can be easily removed from cans by heating to boiling. (Fig. 16.) The cans should be reparaffined.

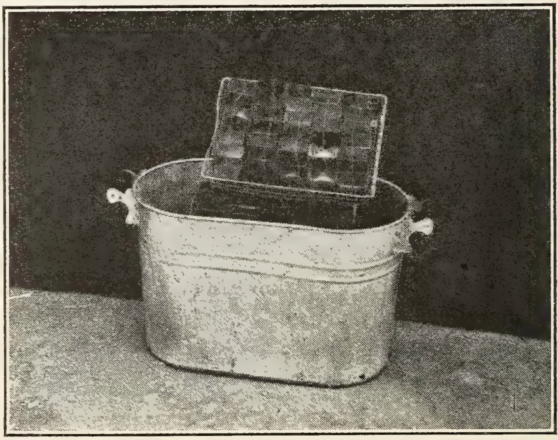


FIG. 16.—Cleaning crystallized sirup from container. Cans are arranged in trays and boiled in water, after which the contents are quickly removed by inverting the trays.

NUMBER OF CONTAINERS.

A container should be attached to each tree in orchards over run with ants. The ants colonize around the base of the trees where the food supply is plentiful, and in clean-cultivated orchards, such as are common in California, and are seldom found between the rows of trees. When food becomes scarce, movement from one tree to another is more common. One striking case of the restricted movement of ants in well-cultivated orchards was observed in an orchard during the spring of 1920. One row of trees near the center of the orchard was missed at the time of sirup distribution, and the first inspection showed the ants almost totally eradicated throughout the orchard with the exception of this one row, which continued to be heavily infested. During experimental work groups of trees in one side of an orchard have had the ants controlled through sirup distribution although the rows bordering these trees were little influenced. Orchards in which only part of the trees are attended by ants need sirup containers only on the infested trees. In California the plantings are for the most part from 70 to 100 trees to the acre.

COMPARATIVE COST OF TINS AND PARAFFINED BAGS.

The cost of ant sirup fluctuated greatly during the period of experimental work, 1917 to 1920, largely because of the changing price of sugar and honey. The cost of materials for each gallon of sirup in 1917 was $0.61 compared to $1.54 in 1920. The cost of the 2-ounce flat spice tins increased about 20 per cent, while paper bags increased over 35 per cent in price. The labor cost also materially increased. The following comparison is based on 1920 prices:

TABLE 2.—*Showing the comparative cost of poisoning ants when using tins and when using paraffined bags, season of 1920.*

Two-ounce flat spice tins.			One-fourth-pound paraffined bags.		
Ant sirup for 100 cans[1]		$1.83	Ant sirup for 100 bags[1]		$1.83
100 2-ounce spice tins		1.75	100 ¼-pound bags		.15
1 pound paraffin		.25	1 pound paraffin		.25
100 2d. finishing nails		.015	100 6-ounce tacks		.025
LABOR.[2]			LABOR.[2]		
Punching and dipping 100 cans	1½ hours.		Punching and dipping 100 bags	1½ hours.	
Filling and capping 100 cans	½ hour.		Filling and closing 100 bags	½ hour.	
Distributing	1 hour.		Distributing	¾ hour.	
At $0.39	3 hours.	1.17	At $0.39	2¾ hours.	1.07
Total		5.015	Total		3.325
Total cost per can		.05	Total cost per bag		.03⅓

[1] Based on 84 cans to the gallon at $1.54 per gallon.
[2] This does not include time spent in preparing sirup.

INFLUENCE OF CONTAINERS ON FEEDING.

Although both paraffined paper sacks and tin cans have been used by the writers for approximately three years, no difference in feeding or rapidity of control attributable to the type of container was observed. It has been stated by some experienced in ant control that greater feeding and more rapid control are effected by the use of paraffined paper bags. An experiment to determine this point was started in 1920 and the results are presented herewith: Sirup was put out on 46 trees in ¼-pound paraffined bags and on 46 trees in 2-ounce paraffined spice tins. Frequent inspections were made of the feeding habits and careful attention paid to any apparent preference for either type of container. The experiment was conducted for two months and percentages figured showing the relative feeding habits. An average of 63 per cent of the bags were attended during the period, and an average of 62 per cent of the cans were fed upon. The ants showed no apparent preference for one type of container over the other. It has been observed that evaporation is more rapid in the bags than in the cans, hastening thickening of the sirup.

FACTORS INFLUENCING CONTROL.

The control of the Argentine ant under California conditions is very variable. In some cases control has been effected within one to two months and occasionally eradication within a like period. In others not even a noticeble reduction of ants has been accomplished within a much longer period. Inspection of containers in certain orchards has shown an occasional ant to feed for several weeks after distribution, while in other cases containers would be swarming with ants within a few hours after the sirup was placed within reach. As a general rule, however, the feeding is heaviest for the first few days when the sirup is fresh; after this the attractiveness is somewhat reduced.

WEATHER.

The weather, especially the temperature, appears to influence feeding greatly. During the hot summer months an arsenical sirup is less attractive than at any other time of the year, and control is slow, frequently unsatisfactory. The ants at this period are exceedingly active, and heavy streams have been known to pass up and down the trunk for weeks at a time, in some cases even right up against the container, without being influenced in the least by the proximity of the sirup. This extreme indifference to sirup is the exception rather than the rule. The maximum temperature at which ants actually slacken or stop activity has never been noted, but the senior writer has observed ants moving freely along the tree trunks at a temperature of 117° F., a degree of heat that proved destructive to many Diptera and Neuroptera. The writers have observed that the movement of ants becomes sluggish as the temperature of 50° F. is approached, and it is during these periods of low temperature that the sirup appears to prove most effective. The tendency of the ants is to cluster close together during the cool mornings in spring and autumn, especially in and about the crotch of the tree. If containers of sirup are present they prove a center of attraction and are frequently attended in large numbers.

FOOD SUPPLY.

Trees severely infested with mealybugs or other honeydew-exuding insects offer a favorable food supply for the Argentine ant. Control on such trees is difficult at any time of the year and usually not to be accomplished during the summer merely by the distribution of sirup, for the ants prefer their natural food to that furnished artificially. The only way to control the ants under such conditions is to remove the insects furnishing the natural food supply, prevent access of the ants to these insects, or else await the autumn or spring when the natural food becomes much reduced and the cold weather promotes feeding on the poisoned sirup. As an illustration of this condition the case of an orchard at Sierra Madre might be mentioned. On June 1, 100 bags of ant poison were distributed in one corner of the orchard, which at the time contained a few mealybugs. Within two months the ants on these trees had been brought under control. On August 1 poison bags were distributed throughout the rest (about 10 acres) of this ant-infested orchard, which was then severely infested with mealybugs. An inspection on October 19 showed no noticeable reduction of ants throughout that part covered by ant sirup in August. The infestation of mealybugs also continued to be severe. With the approach of cold weather and reduction of the numbers of mealybugs the ants fed greedily on the sirup, and by the following spring were practically under control.

On April 26, 1918, ant sirup was placed on 68 large orange trees at Pasadena severely infested with mealybugs. Forty-two of these trees were banded above the sirup cans to prevent the ants reaching the mealybugs, and the remaining 24 were left unbanded. An inspection on April 30 showed large numbers of ants attending the sirup on the banded trees, but not a single can on the unbanded trees was sought by the ants. The second plot was ultimately banded to compel feeding and accomplish control.

During the blossoming period ants are attracted to the nectar within the flowers and control is sometimes difficult, especially during a period of warm weather.

Thus, any attempt at control should give due consideration to the natural food supply of the pest.

Excellent results in complete ant eradication have been obtained in orchards heavily infested with the soft-brown scale and the black scale by following up the usual fall fumigation practice with ant control.

SEASON FOR CONTROL.

The spring and autumn, because of the temperature and food supply, are the periods when control or eradication is most quickly effected in southern California. When the ants break up their winter colonies in the spring, their instinct to multiply leads to an aggressive search for food at a time when the supply is scarce. Consequently, they feed ravenously at this time on ant sirup when offered. It is also during the spring and autumn that the night temperature approaches 50° F., which reduces ant activity, causes the ants to congregate in or about tree crotches of the main limbs, and greatly increases feeding, particularly in the case of trees infested with honeydew-producing insects. During the hot summer months, when the temperature seldom drops to 50° F., ants are active both night and day, and where other food is available they are not greatly attracted by the poisoned sirup.

This temperature influence, and the further important consideration that scale control by fumigation is confined largely to the autumn months, make the fall and spring desirable periods for poisoning the Argentine ant. The writers recommend that control be started between the time ants first appear in the spring and July 1, or from the last of September until congregation into winter colonies takes place. The time of the appearance of ants in the spring varies from year to year, as well as from locality to locality. In 1916 ant activity started the last week in February, whereas in 1920 it was about the middle of April before the winter colonies began to break up. With the approach of cold weather, which normally sets in during December, ants disappear from the trees, although in a very open winter, as that of 1917, complete winter colonizing does not occur.

REAPPEARANCE OF OTHER ANTS FOLLOWING CONTROL OF THE ARGENTINE SPECIES.

It has been stated by Newell that the Argentine ant will not tolerate the presence of other species of ants within its domains. In southern California the commonest species of ant in citrus groves not entirely overrun with the Argentine ant is *Prenolepis imparis* Say. *Formica cinerea* Mayr, var. *pilicornis* Emery ranks second, and *Tapinoma sessile* Say, *Dorymyrmex pyramicus* Roger, and *Cremastogaster lineolata* Say, var. *californica* Emery are of lesser importance. Orchards long infested with Argentine ants are entirely freed of these other species. The reappearance of *Prenolepis imparis* closely following the eradication of the Argentine ant has often been noted, particularly during the autumn and early winter months. One striking instance occurred in 1918 at Pasadena, where ant control was started in April on 258 trees, 4 of which were frequented with Prenolepis. These four infestations of Prenolepis were eradicated, and the Argentines on the other trees were brought under control during the summer and totally eradicated during the month of November, with the exception of a few trees in one corner. On October 17 Prenolepis reappeared on 1 marginal tree and by November 15 had spread to 41. By the middle of December this ant had established colonies throughout the orchard, with the exception of the corner where the Argentine species still maintained a foothold. Several instances of like incursions, but in lesser degree, occurred in orchards at Upland in 1918 and at Alhambra in 1919.

Relation of Breeding to Control.

The most rapid and conspicuous increase in numbers of ants is during the months of July, August, and September, and this is accounted for by the high mean temperatures prevailing during that period and the abundance of available food. High temperatures stimulate the queen to maximum egg production, and the life cycle of workers from egg to maturity under these most favorable weather conditions approaches four to five weeks, instead of two to four months, as during the coldest weather. Since the Argentine ant has been observed to slacken activity at temperatures below 60° F., it is apparent that during the spring and autumn not only does the egg production become greatly reduced, but the period of development is lengthened. Therefore, poison distributed during the spring and autumn should prove most effective.

During the hot summer months when all stages are present and the development is so swift the rapid destruction of all workers present at the time of sirup distribution would not clean up the infestation because additional workers would be daily emerging from the pupæ and these could care for the undeveloped larvæ. Eradication of the young during the summer by poisoning of workers is less likely at this time than during the period of slow development.

CONTROL ON MARGINAL TREES.

Ant eradication has been most difficult on the outside rows of orchards, particularly so when bordered by ditches or strips of uncultivated land. In clean-cultivated orchards, as stated elsewhere in this bulletin, there is little movement between trees, yet the marginal rows are commonly attended by ants breeding in the strips of bordering ground. If this adjacent territory is heavily colonized by ants, the latter will be attracted by sirup on these trees. The greatest difficulty has been experienced at times in eradicating ants from these trees, and ants have been eradicated from entire large orchards with the exception of outside trees. The difference in rapidity of eradication between the marginal two rows of trees and the rest of a 10-acre orchard by the sirup method is shown in figure 17. Orchards from which ants have been entirely eradicated one year have been known to have the outside two to three rows reinfested the following year from adjacent ant-sustaining territory. As a matter of precaution it is sometimes advisable to keep containers of sirup on the outside row of trees even after ants have been eradicated from an orchard. Such action, if long continued, ultimately will result in reduction or control of the ants in the immediately adjoining strip of land and will act as a protection to the rest of the orchard. Particularly necessary is it to keep up the fight on house-lot property. The writers have totally eradicated ants from small city properties only to have incursions a short time later from the outside.

CLEAN CULTURE.

Ant eradication by the sirup method is difficult in uncultivated orchards or in orchards with rank vegetation beneath the trees. (Fig. 18.) Weeds and grass harbor plant-lice, scales, and other insects which furnish honeydew and distract the ants from the sirup. Such growth in contact with the branches offers avenues of travel distant from the poison. Clean culture should be practiced and, where possible, the lower branches pruned to prevent access to the tree except by the trunk. (Fig. 19.)

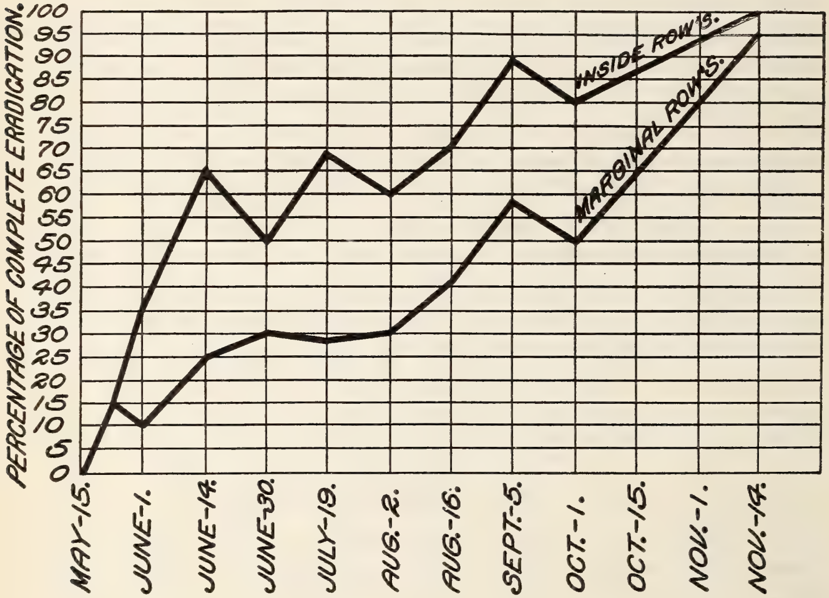


FIG. 17.—Comparative progress of ant eradication on marginal and inside rows of a 10-acre citrus orchard.

CONTROL ON HOUSE LOTS OR ABOUT BUILDINGS.

The control of ants on house lots or about buildings requires greater attention than does orchard work and furthermore is slower. Ground traps are advantageous in addition to the regular field containers. In order to effect rapid reduction of the pest, liberal distribution of containers has been found advisable. It has been the custom of the

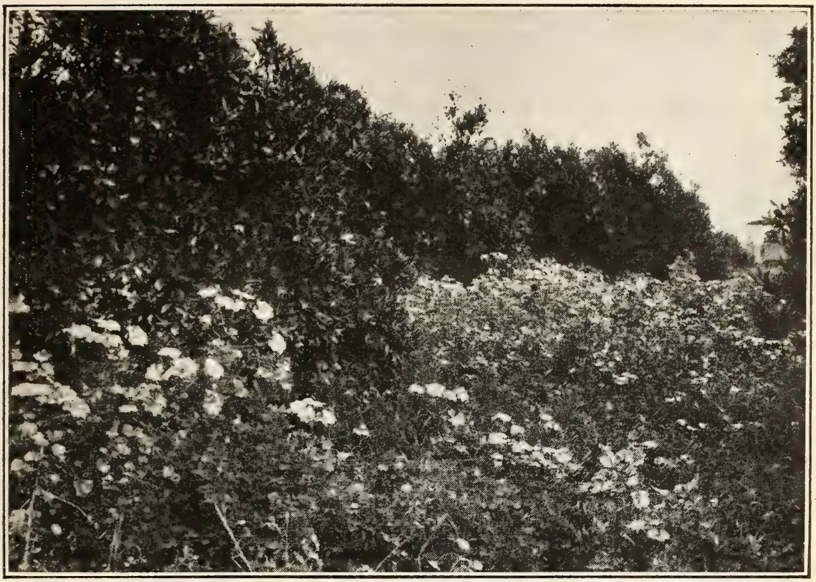


FIG. 18.—A citrus orchard in which clean culture is not practiced. It is difficult to obtain ant control by the poisoned-sirup method on such property.

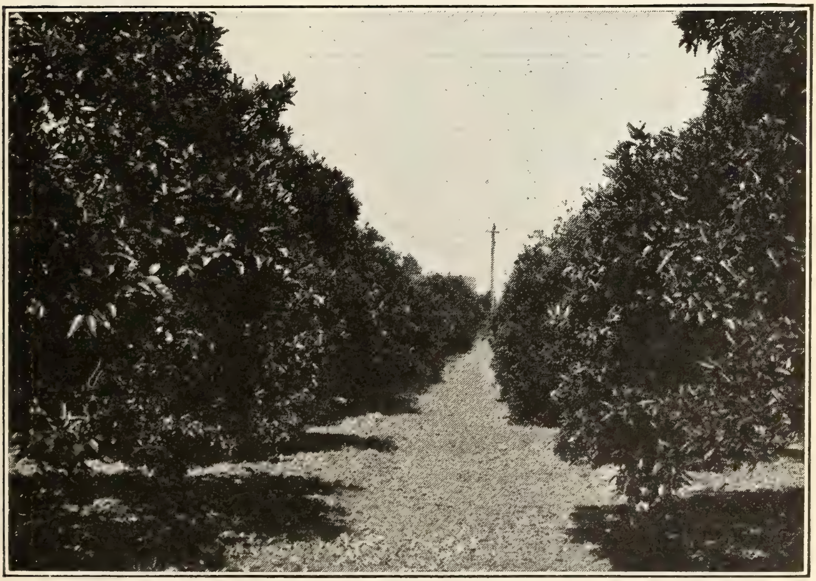


FIG. 19.—Citrus orchard showing clean cultivation, a condition necessary if rapid ant control by the use of the poisoned sirup is to be secured.

writers to hang a container on each tree or shrub about the property and to place several about the house along the foundation where trails of ants are found. Where ant-frequented property adjoins, it is well to distribute containers at the margin. They can be tacked in protected places on fences or to hedges. Ground traps should be placed along sidewalks and about lawns where trails are located. A satisfactory distribution of containers on a 50 by 200 foot lot is shown in figure 20.

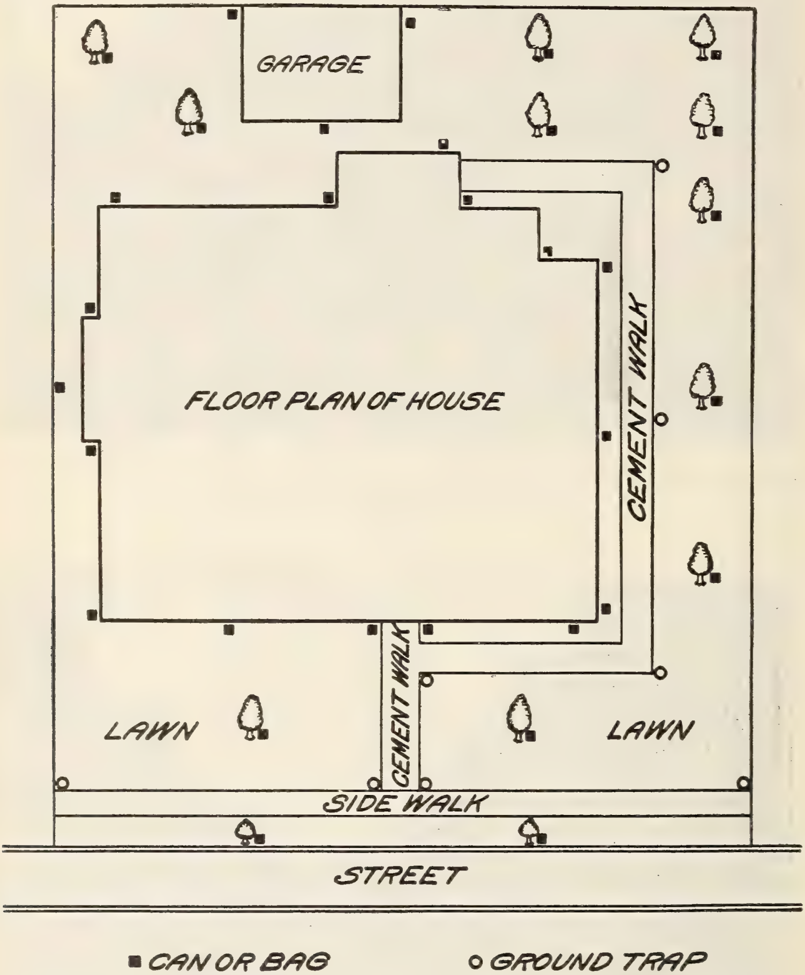


FIG. 20.—Diagram of residential property showing distribution of poisoned-sirup containers.

COMPREHENSIVE DEMONSTRATION OF CONTROL.

A campaign directed toward the control of the citrophilus mealybug was started at Upland in 1917, and it was soon discovered that the 600 infested acres were entirely overrun with the Argentine ant.

Therefore an effort to eliminate the ant was immediately started, and on August 28 ant poison prepared according to the original Barber formula was placed in paraffined paper bags on a 2-acre demonstration orchard, a bag to each tree. Within two weeks the effectiveness of the sirup was apparent, a reduction of fully 50 per cent being shown over the adjacent untreated trees. Within a month the ants were under control on most of the trees.

This very successful demonstration proved immediately convincing to orchardists in the neighborhood, and by the months of September and October the owners, representing 160 acres of infested orchards, had been induced to attempt ant control. During 1918 the territory covered was greatly extended and by the end of the year the treated territory had been brought up to 490 acres, or only 110 short of the entire mealybug-infested territory. These 110 acres were placed under control during the spring of 1919.

The methods which have been put into operation by the writers and are fully presented under demonstration orchard B were applied throughout the campaign. The original Barber poisoned sirup was used during 1917, but in 1918 the modified more dilute sirup was adopted and subsequently used exclusively. A very large amount of the poisoned sirup was prepared under the direction of the junior author or was supplied by qualified druggists. Spice tins were used very largely as containers.

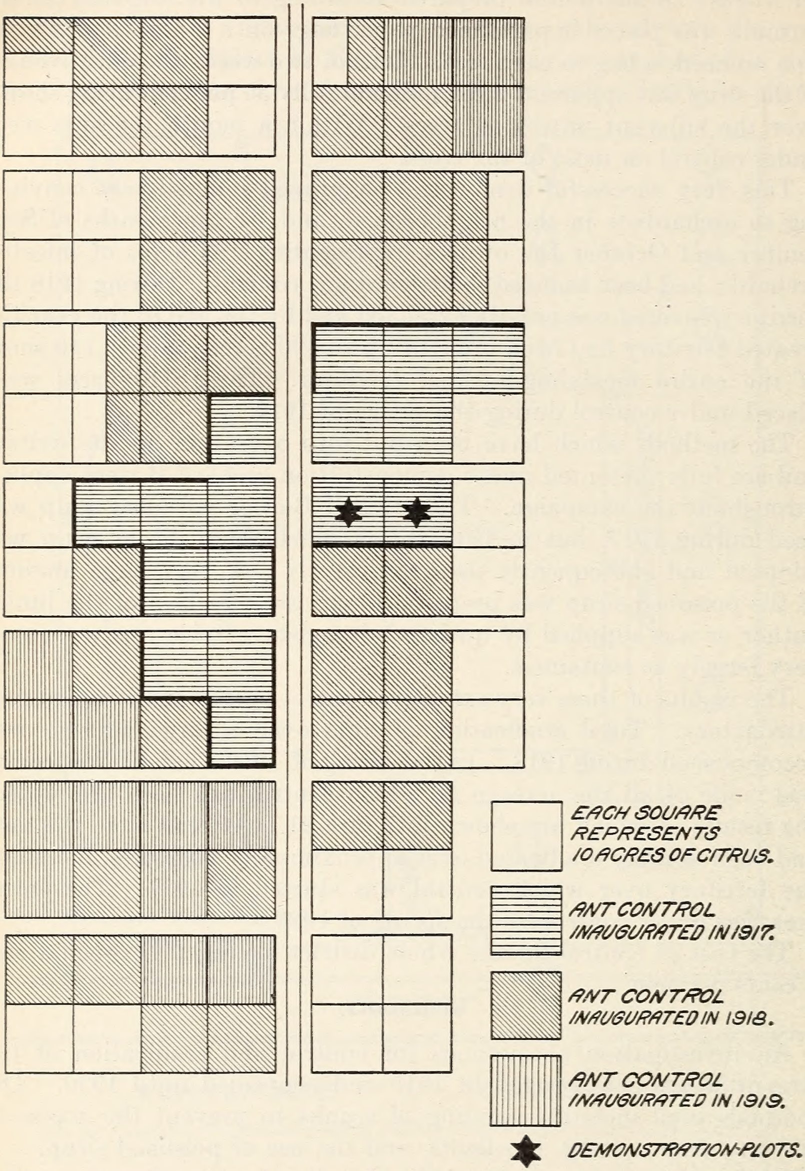
The results of these very extensive control operations were entirely satisfactory. Total eradication of ants over a large acreage was accomplished during 1918. In the spring of 1919 a careful inspection was made of all the acreage on which control had been attempted, the results of which are shown in figure 21. At that time the ants had been entirely eradicated over approximately 450 acres, including the territory over which control was started in 1917. The entire area was under control by the spring of 1920.

The cost of control for the whole district averaged between 4 and 5 cents per tree.

SUMMARY.

An investigation of methods for control and eradication of the Argentine ant was started in 1915 and continued until 1920. The methods used included banding of trunks to prevent the access of the ant, trap nesting, repellents, and the use of poisoned sirup.

Of the various substances tried in banding, a mixture composed of 1 part of sulphur and 6 parts of commercial sticky tree-banding material proved most satisfactory. The careful attention necessary to keep the bands in a freshened condition, their high cost, and the ourstanding fact that the ants remained an everlasting menace, however, led to their discontinuance.


EACH SQUARE REPRESENTS 10 ACRES OF CITRUS.
ANT CONTROL INAUGURATED IN 1917.
ANT CONTROL INAUGURATED IN 1918.
ANT CONTROL INAUGURATED IN 1919.
DEMONSTRATION PLOTS.

YEAR	1917	1918	1919	TOTAL
NEW AREA UNDER CONTROL	160	330	140	630
COMPLETE ANT ERADICATION		150	300	450
ENTIRE AREA UNDER CONTROL IN 1920.				

FIG. 21.—Diagram of the area under Argentine ant control at Upland, Calif., 1917–1919.

Trap nesting proved to be impractical under southern California conditions because of the light average rainfall and the excessive cost as compared with that of the use of a poisoned sirup.

Repellents, in the form of corrosive-sublimate bands and powders prepared from pyrethrum and sodium fluorid, were found to have a limited use about residences, apiaries, etc.

The most practical means of control was the complete eradication obtained by the use of an arsenical poisoned sirup. Numerous formulas were prepared and tried in large field experiments. Of these the original Barber formula proved effective, but was objectionable because of rapid crystallization. Various modified formulas were used and one finally adopted which contained all the ingredients of the Barber formula, somewhat reapportioned, and, in addition, the preservative benzoate of soda. The modified formula gives a much thinner sirup, one of greater stability, and also a considerably cheaper one. The arsenical poisoned sirups have been used in various parts of southern California on almost 3,000 acres of citrus with excellent results. Ants have been totally eradicated from many hundreds of acres with one or two applications. It is essential that the sirup be carefully and properly prepared.

Orchard control.—In orchard distribution approximately 1½ ounces of sirup are placed in a 4-ounce spice tin with a few strands of excelsior, and such a tin is hung on the trunk or a main branch of each infested tree. Spring and autumn are the preferred periods for this work. Monthly inspection should be made and empty and removed containers refilled and replaced. The average cost per tree has been between 4 and 5 cents.

Control about residences.—This method has proved equally successful in eradicating the ants about residences. Much care should be given to bait each trail, at intervals of 10 to 15 feet, with either a spice tin or a ground trap.

The eradication of the Argentine ant has resulted in commercial control of mealybugs and the soft brown scale over a large area in the citrus districts of southern California.

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